

AUTOMATIC CREATION OF PROTOCOL DEPENDENT CONTROL PATH FOR INSTRUMENT APPLICATION

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BACKGROUND

Instruments were historically designed and built to perform a rather limited and well specified set of measurements for fairly well defined applications in localized environments for a specific type of user. However, the advent of large scale integrated circuit technology has provided instrument designers with the ability to cost effectively add more and more capabilities to an instrument.

Many instruments today are now designed to be controlled by a computer, and this computer may be located remotely from the instrument. Instruments have moved from the ability to make, for example, simple voltage and/or current measurements by flipping a switch to the ability to perform multiple tests of multiple types at a high rate of speed without human interaction. In another aspect, the functionality of instruments is becoming more and more dynamic. A user can now purchase options for an instrument that can be turned on and off as, for example, the user pays for licenses for various functionality and/or licenses expire. Standard control and interconnect technologies and protocols have been developed for this combined computer/instrument system.

Modern instruments can now provide a variety of measurement capabilities which are controlled by software programs written for and resident on the instrument using a set of software routines. These routines are often a part of a software suite of functions having a standard format. Such routines are referred to as Application Program(ming) Interface (API) functions. In computers, the operating system, for example, has APIs for a variety of tasks including disk and file control. APIs are written and used in order to provide portable code and are generally available for use by application programmers. Application programmers specify the commands (calls) and the required parameters of the commands necessary to perform a needed task. They do not have to address the details of implementation, which may vary from system to system. In effect, the API's

form a high-level programming language.

Software control of instruments is similarly effected by means of API's written for each instrument. Again, the instrument application developer can write portable, high-level software without having to deal with the more detailed, lower-level implementation details which are more involved and which are instrument specific. The set of API's developed for any given instrument is referred to as the native instrument API's. Programming environments with standard protocols, such as .NET which is an open software standard initially developed by Microsoft, are now used in the creation and running of modern instrument applications.

The use of standard programming and runtime protocol environments has resulted, to some extent, in the ability to reuse prior developed software with the resultant savings in development expense and a reduction in development time with hopefully more reliable software.

SUMMARY

Methods and systems for creating a protocol dependent control path for instrument applications are disclosed herein. In a representative embodiment, identifications of a client, of an instrument application, of a client specific protocol, and of an application specific protocol are obtained. The client is configured to invoke the application and to communicate using the client specific protocol. The application is configured to communicate using the application specific protocol. Then a control path between the client and the application is automatically created.

In another representative embodiment, a system for creating the protocol dependent control path for instrument applications includes a management logic module configured to obtain identification of the client, to obtain identification of the instrument application, to obtain identification of the client specific protocol, to obtain identification of the application specific protocol, and to automatically create the control path between the client and the application. The client is configured to invoke the application and to communicate using a client specific protocol. The application is configured to communicate using a application specific protocol, wherein the application specific protocol differs from the client specific protocol.

Other aspects and advantages of the present representative embodiments will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the representative embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings provide visual representations which will be used to more fully describe various representative embodiments and can be used by those skilled in the art to better understand them and their inherent advantages. In these drawings, like reference numerals identify corresponding elements.

Figure 1 is a block diagram of a measurement system as described in various representative embodiments.

Figure 2 is a block diagram of an embodiment of part of the measurement system of Figure 1.

Figure 3 is a block diagram of another embodiment of part of the measurement system of Figure 1.

Figure 4 is a block diagram of still another embodiment of part of the measurement system of Figure 1.

Figure 5 is a block diagram of yet another embodiment of part of the measurement system of Figure 1.

Figure 6 is a block diagram of the measurement system as described in various representative embodiments.

Figure 7 is a flow chart of a method for creating a control path in a measurement system as described in various representative embodiments.

Figure 8 is a flow chart of a method for measurement system communication as described in various representative embodiments.

Figure 9 is a flow chart of another method for measurement system communication as described in various representative embodiments.

DETAILED DESCRIPTION

As shown in the drawings for purposes of illustration, the present patent document relates to novel techniques for the automatic creation of a protocol dependent control path for an instrument application. Such techniques also include the automatic creation of control paths by multiple users wherein the users may issue commands and queries using different protocols.

Application developers for modern systems such as instruments use a variety of protocols for to create software routines for controlling the instrument. Such routines are referred to as Application Program(ming) Interface (API) functions. The application programmers specify the commands (calls) and any associated parameters that are necessary to perform a needed task. By using API's they do not have to address the details of implementation, which may vary from system to system. In effect, the API's form a high-level programming language. These API's can be written in, for example, Sun Microsystems' Java or .NET. Various users or clients may, however, want to make use of these API's via other protocols, as for example Standard Commands for Programmable Instruments (SCPI) which is a commonly used protocol in the Test and Measurement industry. Other client specified protocols, including, Java and .NET, may also be used.

In representative embodiments, techniques are disclosed wherein various communication protocols are registered with a controller. Once registered, the controller can automatically create an appropriate control path with an associated translator enabling a particular client to communicate with and to control an instrument's application even though the communications issued by the client may be written using a protocol that differs from the protocol of the instrument application API's. In other representative embodiments, multiple users, each using a user specific protocol, can access applications on the instrument.

In the following detailed description and in the several figures of the drawings, like elements are identified with like reference numerals.

Figure 1 is a block diagram of a measurement system **100** as described in various

representative embodiments. In the embodiment of Figure 1, two clients **105** (client 1 and client 2) are each separately connected to two applications **110** (application A and application B), also referred to herein as application modules **110** and application logic modules **110**, on an instrument **115** by communication links **120** and communication modules **123**, also referred to herein as communication logic modules **123**. Each of the clients **105** sends commands **125** to the application **110** on the instrument **115** by means of communication links **120** and communication modules **123**.

Commands **125** controlling instrument **115** functions are generically referred to as remote procedure control (RPC) commands **125** and herein as received commands **125**. RPC commands **125** are formatted by the client **105** before transmission into a client specific communication protocol **127** (not shown explicitly in the drawings), also referred to herein as a client specific protocol **127**. A number of standard sets of program calls or routines referred to as API's are used to control various applications on the instrument **115**. The set of API functions which the applications **110** on the instrument **115** has been programmed to understand are written using RPC functions or commands **125** which are resident on the instrument **115** and which are referred to as the instrument resident or instrument native API's. Similarly, the format or grammar used to write these API's is referred to as the native language of the instrument **115**. The instrument native API's are formatted in conformance to an application specific protocol **129** (not shown explicitly in the drawings). In order to control the instrument **115**, commands **125** reaching instrument measurement software **140** need to conform to the application specific protocol **129**. The communication modules **123** translate the client specific communication protocol **127** commands **125** sent to the instrument **115** by the clients **105** into translated commands **145** having translator protocols **128** (not explicitly shown in the drawings) which the application **110** is capable of understanding and reacting appropriately to.

Standard communication protocols are used in various industries. Standard Commands for Programmable Instruments (SCPI) is one such protocol commonly used in the Test and Measurement industry. SCPI comprises a common set of commands that instruments of a particular type will understand. For example, as a general rule,

voltmeters and spectrum analyzers will understand particular sets of SCPI commands which control various functions on these instruments. Instrument functionality varies depending upon instrument manufacturer and type. Manufacturers enhance product differentiation by the addition of various capabilities to the instrument. SCPI is coded as an ASCII string and has a hierarchical command structure. At an upper level could be an instruction to select the general function to perform, such as measure or calibrate a system or subsystem. The next level could be a more specific statement of what the function is to perform, for example measure a frequency, voltage, or current in the item selected for measurement. Under voltage, for example, might be the type of voltage, i.e., DC voltage (direct current voltage) or AC voltage (alternating current voltage). A command might be "Measure voltage DC". Each of these items "Measure", "Voltage" and "DC" are considered to be a SCPI node. The collection of all SCPI nodes in an instrument is a SCPI tree. In the instrument, a SCPI parser waits and listens for a SCPI command. When the SCPI parser receives a SCPI command that it understands, it identifies the correct SCPI node that corresponds to the SCPI command and instructs that node to perform the requested function.

However, not all instruments use SCPI as the communication protocol for their resident command language API's, and computers used in the control of instruments do not always use a SCPI command set. There are potentially several different communication protocols that the computer can use to communicate with an instrument. In addition to SCPI, a computer or system could use .NET, Java, CORBA which is a standard of the Object Management Group (OMG), or the like.

In Figure 1, a remote procedure control (RPC) input/output (I/O) management module 150, also referred to herein as a management module 150 and as a management logic module 150, identifies which client specific communication protocol 127 each client 105 is using to communicate with the instrument 115. Following registration of the client specific communication protocols 127 with the RPC I/O management module 150, the RPC I/O management module 150 sets up and appropriately configures associated communication modules 123. Among other tasks, each communication module 123, if necessary, transforms the client specific communication protocol 127

commands **125** that it receives from its associated client **105** into translator protocol **128** translated commands **145** which the application **110** can understand.

The application **110** sends instructions from these translated commands **145** to the instrument measurement software **140** which in turn transfers these instructions to instrument firmware **165**. The instrument firmware **165** finally transfers the required instructions to instrument hardware **170** for performing the requested task.

The RPC I/O management module **150** can maintain two internal data structures, a table of exported communication protocols **175** and a table of applications exporting their API's **180**. The table of exported communication protocols **175** comprises a list of all the communication protocols supported by the instrument. The exported communication protocols are referred to as "exported" because they are available for use not only on the instrument **115**, but on the instrument **115** by the clients **105**. In other words, the exported communication protocols are not just available for call by functions internal to the instrument. The table of applications exporting **180** their API's is a table of applications on the instrument **115** that have API's available for use by the clients **105**.

Figure 2 is a block diagram of an embodiment of part of the measurement system **100** of Figure 1. In the embodiment of Figure 2, the communication module **123** comprises a server **205**, also referred to herein as a server module **205** and as a server logic module **205**, and a translator **215**, also referred to herein as a translator module **215** and as a translator logic module **215**. The server module **205** receives commands **125** from its associated client **105** and transfers those commands to the translator module **215**. The translator module **215** translates the commands **125** from the associated client **105**, which commands **125** have a client specific communication protocol **127**, into an appropriate translated command **145**, which commands have the translator protocol **128**, for reception by the application module **110**.

The application module **110** comprises a virtual instrument module **220**, also referred to herein as a virtual instrument logic module **220**, an interface **220**, an interface module **220**, and an interface logic module **220**, and an application component module **210**, also referred to herein as an application component **210** and an application component logic module **210**. The virtual instrument module **220** acts as an interface to

the application component module **210**. It receives the translated command **145** at the input of the virtual instrument **220** and acts as an interface to control the flow of communications between the client **105** and its associated application component **210**. If necessary, the virtual instrument module **220** translates the translated command **145** having translator protocol **128** into an application command **155** having an application specific protocol **129** (not explicitly shown in the drawings) which the application component **210** is capable of understanding and reacting appropriately to. The application component module **210** decodes the commands to the instrument measurement software **140**. For an implementation in which the translator protocol **128** is the same as the application component specific protocol **129**, the translated command **145** is the same as the application command **155**. As such, the virtual instrument **220** will not translate the translated command **145** into the application command **155** but will instead transfer the translated command **145** without change to the application component module **210**.

Messages **225**, referred to herein as application messages **225**, can be sent from the application component module **210** to the associated client **105**. Messages **225** having application specific protocol **129** are transformed by the virtual instrument **220** into intermediate messages **245** having translator protocol **128**. The intermediate messages **245** are then transferred to the translator **215** in the communication module **123**. Messages and commands between one of the clients **105** and its associated application **110** are more generally referred to herein as communications.

For an implementation in which the translator protocol **128** is the same as the application specific protocol **129**, the intermediate message **245** is the same as the application message **225**. As such, the virtual instrument **220** will not translate the application message **225** into the intermediate message **245** but will instead transfer the application message **225** without change to the translator **215** in the communication module **123**.

Intermediate messages **245** having translator protocols **128** are transformed by the translator **215** into client messages **255** having the client specific communication protocol **127**. The client messages **255** are then transferred to the server **205** in the communication

module **123**. The server **205** transfers the client messages **255** to the appropriate client **105** via communication link **120**. For an implementation in which the translator protocol **128** is the same as the client specific communication protocol **127**, the intermediate message **245** is the same as the client message **255**. As such, the translator **215** will not
5 translate the intermediate message **245** into the client message **255** but will instead transfer the intermediate message **245** without change to the server **205** in the communication module **123** for transfer to the associated client **105** via communication link **120**.

Figure 3 is a block diagram of another embodiment of part of the measurement
10 system **100** of Figure 1. In the embodiment of Figure 3, the communication module **123** comprises a server module **205**. The server module **205** receives commands **125** from its associated client **105** and transfers those commands to the application module **110**. The application module **110** comprises a virtual instrument module **220** and an application component module **210**. The virtual instrument module **220** acts as an
15 interface for the application component module **210**. It receives the command **125** which is the same as the translated command **145** at the input of the virtual instrument **220** and acts as an interface to control the flow of communications between the client **105** and its associated application component **210**.

If necessary, the virtual instrument module **220** translates the client command **125**
20 having client specific communication protocol **127** into application command **155** having application specific protocol **129** which the application component **210** is capable of understanding and reacting appropriately to. The application component module **210** decodes the application command **155** and connects to the instrument measurement software **140**. For an implementation in which the translator protocol **128** is the same as
25 the application specific protocol **129**, the client command **125** is the same as the application command **155**. As such, the virtual instrument **220** will not translate the client command **125** into the application command **155** but will instead transfer the client command **125** without change to the application component module **210**.

Application messages **225** can be sent from the application component module
30 **210** to the associated client **105**. Messages **225** having application specific protocol **129**

are transformed by the virtual instrument **220** into intermediate messages **245** having translator protocol **128**. The intermediate messages **245** are then transferred to the server **205** in the communication module **123**.

For an implementation in which the translator protocol **128** is the same as the application specific protocol **129**, the intermediate message **245** is the same as the application message **225**. As such, the virtual instrument **220** will not translate the application message **225** into the intermediate message **245** but will instead transfer the application message **225** without change to the server **205** in the communication module **123**.

Since this embodiment does not include a translator **215**, the intermediate message **245** is the same as the client message **255**. As such, the server will transfer the intermediate message **245** (i.e., the client message **255**) without change to its associated client **105** via communication link **120**.

Figure 4 is a block diagram of still another embodiment of part of the measurement system **100** of Figure 1. In the embodiment of Figure 4, the communication module **123** comprises the server module **205** and the translator **215**. The server module **205** receives commands **125** from its associated client **105** and transfers those commands to the translator module **215**. The translator module **215** translates the commands **125** from the associated client **105**, which commands **125** have a client specific communication protocol **127**, into an appropriate translated command **145**, which commands have the translator protocol **128**, for reception by the application module **110**.

The application module **110** comprises the application component module **210**. The application component module **210** decodes the translated command **145** and connects to the instrument measurement software **140**. Since in this implementation the translator protocol **128** is the same as the application specific protocol **129**, the translated command **145** is the same as the application command **155**. As such, the translated command **145** will be transferred without change to the application component module **210**.

Messages **225**, referred to herein as application messages **225**, can be sent from

the application component module **210** to the associated client **105**. Since in this embodiment, the application specific protocol **129** is identical to the translator protocol **128**. The messages **225** are identical to the intermediate messages **245**. The application messages **225** are, therefore, transferred to the translator **215** in the communication module **123**.

Application messages **225** having application specific protocols **129** are transformed by the translator **215** into client messages **255** having the client specific communication protocol **127**. The client messages **255** are then transferred to the server **205** in the communication module **123**. The server **205** transfers the client messages **255** to the appropriate client **105** via communication link **120**.

For an implementation in which the translator protocol **128** is the same as the client specific communication protocol **127**, the application message **225** is the same as the client message **255**. As such, the translator **215** will not translate the application message **225** into the client message **255** but will instead transfer the application message **225** without change to the server **205** in the communication module **123** for transfer to the associated client **105** via communication link **120**.

Figure 5 is a block diagram of yet another embodiment of part of the measurement system **100** of Figure 1. In the embodiment of Figure 5, the communication module **123** comprises the server module **205**. The server module **205** receives commands **125** from its associated client **105** and transfers those commands to the application module **110**.

The application module **110** comprises the application component module **210**. The application component module **210** decodes the command **125** and connects to the instrument measurement software **140**. Since in this implementation the client specific protocol **127**, the translator protocol **128**, and the application specific protocol **129** are identical, the application command **155** is the same as the command **125** received from the associated client **105**. As such, the command **125** will be transferred without change to the application component module **210**.

Application messages **225** can be sent from the application component module **210** to the associated client **105**. Since in this embodiment, the application specific protocol **129**, the translator protocol **128**, and the client specific communication protocol

127 are identical, client messages 255 are identical to the intermediate messages 245 and to the application messages 225. The application messages 225 are, therefore, transferred to the client 105 via the server module 205 in the communication module 123. The server 205 transfers the application messages 225 to the appropriate client 105 via communication link 120.

Figure 6 is a block diagram of the measurement system 100 as described in various representative embodiments. In the embodiment of Figure 6, clients 105 external to the instrument 115 are shown to the left of instrument boundary 605. All blocks to the right of the instrument boundary 605 are a part of the instrument 115. In the example implementation of Figure 6, the clients 105 of the measurement system 100 are implemented as Java RMI Client 105, .NET Remoting Client 105, CORBA Client 105, and SCPI Client 105 with each having their own client specific communication protocol 127. Servers 205 are implemented as Java RMI Server 205, .NET Remoting Server 205, CORBA Server 205, and SCPI Server 205. Translators 215 are implemented as Java to .NET Translator 215, CORBA to .NET Translator 215, and SCPI to .NET Translator 215. Virtual instruments 220 are implemented as .NET CDMA Virtual Instrument 220, .NET 802.11b Virtual Instrument 220, and .NET Bluetooth Virtual Instrument 220. And, application components 210 are implemented as CDMA Measurement Application 210, IEEE 802.11b Measurement Application 210, and Bluetooth Measurement Application 210. Communication links 120 connect clients 105 with their respective servers 205 on the instrument 115. For clarity of illustration, only one of the communication links 120 is identified by number. Also, only one of the communication modules 123 and only one of the applications 110 are explicitly shown and identified by number in Figure 6.

In the following discussion, it is assumed that communications to and from the application components 210 in the implementation of Figure 6 are in accordance with the .NET protocol. As such, translations of these communications are not required by the virtual instruments 220 for proper system function.

As an example, Java RMI Client 105 communicates with Java RMI Server 205 via one of the communication links 120 using commands 125 and client messages 255 which conform to the Java protocol. Java RMI Server 205 transfers RPC commands 125

in the Java protocol to the Java to .NET Translator **215**. The Java to .NET Translator **215** translates those commands **125** in the Java protocol into translated commands **145** which conform to the .NET protocol. The Java to .NET Translator **215** transfers those translated commands **145** in the .NET protocol to the .NET CDMA Virtual Instrument **220**. The .NET CDMA Virtual Instrument **220** then uses those translated commands **145** in the .NET protocol to control the CDMA Measurement Application **210**.

In another communication path, the .NET Remoting Client **105** communicates with .NET Remoting Server **205** via one of the communication links **120** using commands **125** and client messages **255** which conform to the .NET protocol. For commands **125** intended for the CDMA measurement application **210**, the .NET Remoting Server **205** transfers RPC commands **125** in the .NET protocol to the .NET CDMA Virtual Instrument **220**. The .NET CDMA Virtual Instrument **220** then uses those translated commands **145** in the .NET protocol to control the CDMA Measurement Application **210**. Since the commands **125** are in the .NET protocol when received by the .NET Remoting Server **205**, and since the protocol which the .NET CDMA Virtual Instrument expects and understands is the .NET protocol, commands **125** do not pass through a translator **215**. For commands **125** intended for the IEEE 802.11b measurement application, the .NET Remoting Server **205** transfers RPC commands **125** in the .NET protocol to the .NET 802.11b virtual instrument **220**. The .NET 802.11b virtual instrument **220** then uses those translated commands **145** in the .NET protocol to control the IEEE 802.11b measurement application **210**. Since the commands **125** are in the .NET protocol when received by the .NET Remoting Server **205**, and since the protocol which the IEEE 802.11b measurement application **210** expects is the .NET protocol or the commands **125** are converted to the appropriate protocol by the .NET 802.11b virtual instrument **220**, commands **125** do not pass through a translator **215**.

And, the CORBA Client **105** communicates with CORBA Server **205** via one of the communication links **120** using commands **125** and client messages **255** which conform to the CORBA protocol. CORBA Server **205** transfers RPC commands **125** in the CORBA protocol to the CORBA to .NET Translator **215**. The CORBA to .NET Translator **215** translates those commands **125** in the CORBA protocol into translated

commands **145** which conform to the .NET protocol. The CORBA to .NET Translator **215** transfers those translated commands **145** in the .NET protocol to the .NET 802.11b Virtual Instrument **220**. The .NET 802.11b Virtual Instrument **220** then uses those translated commands **145** in the .NET protocol to control the IEEE 802.11b Measurement
5 Application **210**.

Also, the SCPI Client **105** communicates with SCPI Server **205** via one of the communication links **120** using commands **125** and client messages **255** which conform to the SCPI protocol. SCPI Server **205** transfers RPC commands **125** in the SCPI protocol to the SCPI to .NET Translator **215**. The SCPI to .NET Translator **215**
10 translates those commands **125** in the SCPI protocol into translated commands **145** which conform to the .NET protocol. The SCPI to .NET Translator **215** transfers those translated commands **145** in the .NET protocol to the .NET Bluetooth Virtual Instrument **220**. The .NET Bluetooth Virtual Instrument **220** then uses those translated commands **145** in the .NET protocol to control the Bluetooth Measurement Application **210**.

15 Messages **225** generated by actions in the CDMA Measurement Application **210** related to tasks for the Java RMI Client **105** are transferred in the .NET protocol from the CDMA Measurement Application **210** to the .NET CDMA Virtual Instrument **220** wherein, if necessary, the messages **225** are converted to intermediate messages **245**. The .NET CDMA Virtual Instrument **220** then transfers the intermediate messages **245** to the
20 Java to .NET Translator **215**. The Java to .NET Translator **215** translates those intermediate messages **245** into client messages **255** which conform to the Java protocol. The Java to .NET Translator **215** transfers these **255** in the Java protocol to the Java RMI Server **205**. The Java RMI Server **205** then transfers those messages **255** in the Java protocol to the Java RMI Client **105** via one of the communication links **120**.

25 In another communication path, messages **225** generated by actions in the CDMA Measurement Application **210** related to tasks for the .NET Remoting Client **105** are transferred in the .NET protocol from the .NET CDMA Virtual Instrument **220** to the to the .NET Remoting Server **205**. The .NET Remoting Server **205** then transfers those messages **225** in the .NET protocol to the .NET Remoting Client **105** via one of the
30 communication links **120**.

And, messages **225** generated by actions in the IEEE 802.11b Measurement Application **210** related to tasks for the .NET Remoting Client **105** are transferred in the .NET protocol from the .NET 801.11b Virtual Instrument **220** to the to the .NET Remoting Server **205**. The .NET Remoting Server **205** then transfers those messages **245** in the .NET protocol to the .NET Remoting Client **105** via one of the communication links **120**.

Also, messages **225** generated by actions in the CDMA Measurement Application **210** related to tasks for the CORBA Client **105** are transferred in the .NET protocol from the IEEE802.11b Measurement Application **210** to the .NET 802.11b Virtual Instrument **220** wherein, if necessary, the messages **225** are converted to intermediate messages **245**. The .NET 802.11b Virtual Instrument **220** then transfers the intermediate messages **245** to the CORBA to .NET Translator **215**. The CORBA to .NET Translator **215** translates those intermediate messages **245** into client messages **255** which conform to the CORBA protocol. The CORBA to .NET Translator **215** transfers these client messages **255** in the CORBA protocol to the CORBA Server **205**. The CORBA Server **205** then transfers those messages **255** in the CORBA protocol to the CORBA Client **105** via one of the communication links **120**.

In addition, messages **225** generated by actions in the Bluetooth Measurement Application **210** related to tasks for the SCPI Client **105** are transferred in the .NET protocol from the Bluetooth Measurement Application **210** to the .NET Bluetooth Virtual Instrument **220** wherein, if necessary, the messages **225** are converted to intermediate messages **245**. The .NET Bluetooth Virtual Instrument **220** then transfers the intermediate messages **245** to the SCPI to .NET Translator **215**. The SCPI to .NET Translator **215** translates those intermediate messages **245** into client messages **255** which conform to the SCPI protocol. The SCPI to .NET Translator **215** transfers these **255** in the SCPI protocol to the SCPI Server **205**. The SCPI Server **205** then transfers those messages **255** in the SCPI protocol to the SCPI Client **105** via one of the communication links **120**.

Figure 7 is a flow chart of a method **700** for creating a control path in a measurement system as described in various representative embodiments. In block **705**

of Figure 7, the RPC I/O management module **150** obtains client **105** identification from one of the clients **105** intending to invoke an application **110** on the instrument **115** and optionally records that information. Block **705** then transfers control to block **710**.

5 In block **710**, the RPC I/O management module **150** obtains identification as to the applications **110** which the identified client **105** intends to invoke and optionally records that information. Block **710** then transfers control to block **715**.

In block **715**, the RPC I/O management module **150** obtains identification of which client specific communication protocol **127** the commands **125** which may be contained within a client **105** program and messages **255** of the identified client **105** will
10 use for invoking the identified application **110** on the instrument **115** and optionally records that information. Block **715** then transfers control to block **720**.

In block **720**, the RPC I/O management module **150** obtains identification as to which application specific protocol **129** the identified application **110** understands and communicates in and optionally records that information. Block **720** then transfers
15 control to block **725**.

In block **725**, the RPC I/O management module **150** creates a control path between the identified client **105** and the application **110** which the identified client **105** intends to invoke and optionally records that information. Block **725** then terminates the process. However for multiple clients, the above process can be repeated for each client
20 **105**.

Figure 8 is a flow chart of a method **800** for measurement system communication as described in various representative embodiments. In block **805** of Figure 8, the command **125** is received from the client **105**. The command **125** is typically received by the server module **205**. Block **805** then transfers control to block **810**.

25 In block **810**, a determination is made as to which client **105** sent the command **125**. Information as to which client **105** sent the command **125** is typically contained within the command **125**, attached to the command **125**, or encapsulating the command **125**. The determination as to which client **105** sent the command may be ascertained by the server module **205**, the translator module **215**, the virtual instrument module **220**, the
30 application component **210**, and/or other appropriate module. Block **810** then transfers

control to block **815**.

In block **815**, a determination is made as to the destination application **110** and/or application component **210** for the command **125**. Information as to the destination application **110** and/or destination application component **210** is typically contained within the command **125**, attached to the command **125**, or encapsulating the command **125**. The determination as to the destination application **110** and/or destination application component **210** can be performed by the server module **205**, the translator module **215**, the virtual instrument module **220**, the application component **210**, and/or other appropriate module. Block **815** then transfers control to block **820**.

When the protocol of the command **125** as received by the instrument **115** (the client specific communication protocol **127**) differs from the native application protocol (the translator protocol **128** and/or the application specific protocol **129**), block **820** transfers control to block **825**. Otherwise, block **820** transfers control to block **835**.

In block **825**, the command **125** as received from the client **105** is translated into an application command **155** having the native application protocol (the translator protocol **128** or the application specific protocol **129**). Block **825** then transfers control to block **830**.

In block **830**, the application command **155** is transferred to the destination application component **210**, and block **830** then terminates the process.

In block **835**, the received command **125** is transferred to the destination application component **210**, and block **835** then terminates the process.

Figure 9 is a flow chart of another method **900** for measurement system communication as described in various representative embodiments. In block **905** of Figure 9, the message **225** is obtained. The message **225** is typically obtained from the application component module **210** or the virtual instrument module **220**. Block **905** then transfers control to block **910**.

In block **910**, a determination is made as to which client **105** the message **225** will be sent. Information as to which client **105** to send the message **225** is typically contained within the message **225**, attached to the message **225**, or encapsulating the message **225**. The determination as to which client **105** to send the message **225** to may

be ascertained by the server module **205**, the translator module **215**, the virtual instrument module **220**, the application component **210**, and/or other appropriate module. Block **910** then transfers control to block **915**.

When the protocol of the message **225** as obtained by the application component **210** (the application specific protocol **129**) differs from the client protocol (the client specific communication protocol **127**), block **915** transfers control to block **920**. Otherwise, block **915** transfers control to block **930**.

In block **920**, the message **225** as obtained is translated into a client message **255** having the client protocol (the client specific communication protocol **127**). Block **920** then transfers control to block **925**.

In block **925**, the client message **255** is transferred to the destination client **105**, and block **925** then terminates the process.

In block **930**, the client message **255** is transferred to the destination client **105**, and block **930** then terminates the process.

In representative embodiments, the determination of which clients **105** are connected to the instrument **115**, which application modules **110** are available for use on the instrument **115**, and which different types of protocols each of these items uses is performed automatically. Typically the commands **125** are method calls that the clients **105** send to the instrument **115**. These method calls are calls to API's. The API's are then executed on the instrument **115**. The clients **105** can be computers and can be located on the instrument **115** or remote from it.

A given instrument **115** may comprise several different functional capabilities which may be individually purchased by a customer. Such functional capabilities can be turned on/off as, for example, a license is purchased by the user or the license expires. In addition, future applications can be developed after shipment of the instrument to the customer. This added functionality can be installed as such functions are developed by the manufacturer and obtained by the user.

Referring to Figure 1, in representative embodiments it is the RPC I/O management module **150** that creates the interface between the type of client (client 1 and client 2) and the functionality of the instrument **115** (application A and application B).

Application A and application B are the sets of functionality that are inside the instrument 115. The RPC I/O Management module 150 automatically creates the connections between the various clients 105 and the various application components 210, i.e., the RCP I/O management module 150 creates the control paths. A control path is the path that commands 125 and messages 225 take between one of the clients 105 and the application 110 that the client 105 invokes. These control paths can be created dynamically. They can be created when the instrument 115 is powered-up and/or during operation as clients 105 and/or application components 210 are added to the measurement system 100. The RPC I/O management module 150 is capable of automatically detecting which clients 105 and their types (their protocols), and which application components 210 are available for use on the instrument 115. In essence, the RPC I/O management module 150 can permit use of any of a set of application components 210 on the instrument 115 by any of a set of clients 105 connected to the instrument 115.

As is the case, in many data-processing products, the measurement system 100 may be implemented as a combination of hardware and software components. Moreover, the functionality required for implementing various embodiments may be stored on computer-readable media (such as, but not limited to, floppy disks, conventional hard disks, DVD's, CD-ROM's, Flash ROM's, nonvolatile ROM, and RAM) to be used in programming an information-processing apparatus (e.g., a personal computer and/ or instrument) to perform in accordance with the embodiments.

The term "program storage medium" is broadly defined herein to include any kind of computer memory such as, but not limited to, floppy disks, conventional hard disks, DVD's, CD's, Flash ROM's, nonvolatile ROM, and RAM.

In summary, techniques are disclosed in representative embodiments herein wherein various communication protocols are registered with a controller. Once registered, the controller can automatically create an appropriate control path with an associated translator enabling a particular client to communicate with and to control an instrument's application even though the communications issued by the client may be written using a protocol that differs from the protocol of the instrument application API's.

In other representative embodiments, multiple users, each using a user specific protocol,

can access applications on the instrument.

Advantages of the representative embodiments describe herein are that multiple users using multiple protocols can control multiple application components on a single instrument with little or no extra effort by the users. The users may be located on the
5 instrument **115** remotely from it.

While the present invention has been described in detail in relation to preferred embodiments thereof, the described embodiments have been presented by way of example and not by way of limitation. It will be understood by those skilled in the art that various changes may be made in the form and details of the described embodiments
10 resulting in equivalent embodiments that remain within the scope of the appended claims.